Konkola Copper Mines plc

ABSTRACT
This report summarizes the practical experience gained at the KCM Smelter, highlighting work in power distribution, motor maintenance, electrical testing, and equipment installation at Substation

INDUSTRIAL INTERNSHIP REPORT

KCM SMELTER

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Introduction

This internship served as a critical link between academic training and practical engineering application. It provided a platform for applying theoretical principles, developing hands-on technical skills, and gaining exposure to the operational, technical, and safety standards that govern professional industrial environments. The report documents the experience and competencies acquired during the internship at the KCM Smelter, one of the largest and most technologically advanced metallurgical facilities in the region.

The internship involved direct participation in the operation and maintenance of electrical power systems that support smelting operations. Under the supervision of experienced engineers and technicians, activities included power distribution monitoring, motor maintenance, electrical testing, condition monitoring, and equipment installation. These practical engagements enhanced technical proficiency while strengthening understanding of industrial system reliability, teamwork dynamics, and engineering problem-solving methodologies.

The report provides a detailed account of the tasks undertaken, the knowledge acquired, and the professional development achieved throughout the training period. It also emphasizes the significance of practical industrial exposure in preparing engineering students for effective contribution to the sector.

Before presenting the specific tasks completed, it is important to outline the essential role of the electrical engineering department in maintaining continuous and efficient smelter operation. A thorough understanding of the overall process was required to provide the necessary context for informed maintenance decision-making, particularly when prioritizing equipment requiring urgent attention in situations involving multiple simultaneous system issues.

Process Description

Feed Preparation and Drying

The smelting process begins with the preparation of copper concentrate, delivered at 112.3 t/h and containing 36.7% Cu. The material is initially processed in a steam dryer, where moisture is removed to enhance combustion efficiency and furnace stability. A fluxing agent, limestone (4.8 t/h), is blended with the dried concentrate to facilitate slag formation during smelting.

Flash Smelting Furnace (FSF)

The dried feed enters the Flash Smelting Furnace (FSF) alongside oxygen-enriched air (34,400 Nm^3/h at 59.5% O_2). Rapid oxidation and high-temperature reactions produce two molten phases:

- FSF Matte: 67.4 t/h
- FSF Slag: 56.4 t/h

In addition, the furnace generates SO_2-rich process gas (35.2% SO_2), suitable for sulfuric acid production.

Heat Recovery and Gas Cleaning

Off-gases from the FSF flow through the Waste Heat Boiler (WHB), where thermal energy is recovered as steam. Dust is removed in the Electrostatic Precipitator (ESP), which captures 14.0 t/h of flue dust for recycling. The cleaned gas stream is subsequently diverted to the Acid Plant.

Slag Cleaning Furnace (SCF)

Molten FSF slag is transferred to the Slag Cleaning Furnace (SCF). This furnace is designed to recover copper and other valuable metals that remain entrained in the slag from the flash furnace. Through controlled reduction and settling, two products are formed:

- SCF Matte / Cleaned Metal Phase: 10.1 t/h, rich in copper and returned to downstream refining units

- SCF Slag: 56.4 t/h, with reduced metal content

This stage ensures minimal copper losses and significantly improves overall process efficiency.

Cobalt Recovery Furnaces (CoRF1 and CoRF2)

Slag streams from the SCF are further processed in the Cobalt Recovery Furnaces (CoRF1 and CoRF2). These units extract valuable cobalt, copper, and alloy fractions from furnace slag. The products include:

- Co-alloy: 4.3 t/h, containing cobalt and copper values
- Waste Slag: 51.0 t/h, discarded after metal recovery

Anode Furnaces and Casting

Blister copper from the FSF (30.0 t/h) and the cleaned matte from the SCF are fed into the Anode Furnaces. Here, oxidation–reduction cycles remove remaining impurities and dissolved gases. The refined molten copper is then poured into molds to produce anodes, which serve as feedstock for electrorefining.

Integrated Efficiency and Environmental Control

The process incorporates multiple recycling and energy recovery loops, including:

- Recycling of flue dust
- Metal recovery from slag via SCF and CoRF
- Waste heat recovery via the WHB
- Gas cleaning via ESP
- SO_2 conversion in the Acid Plant

This integration reduces energy consumption, improves metal yield, and ensures compliance with environmental standards.

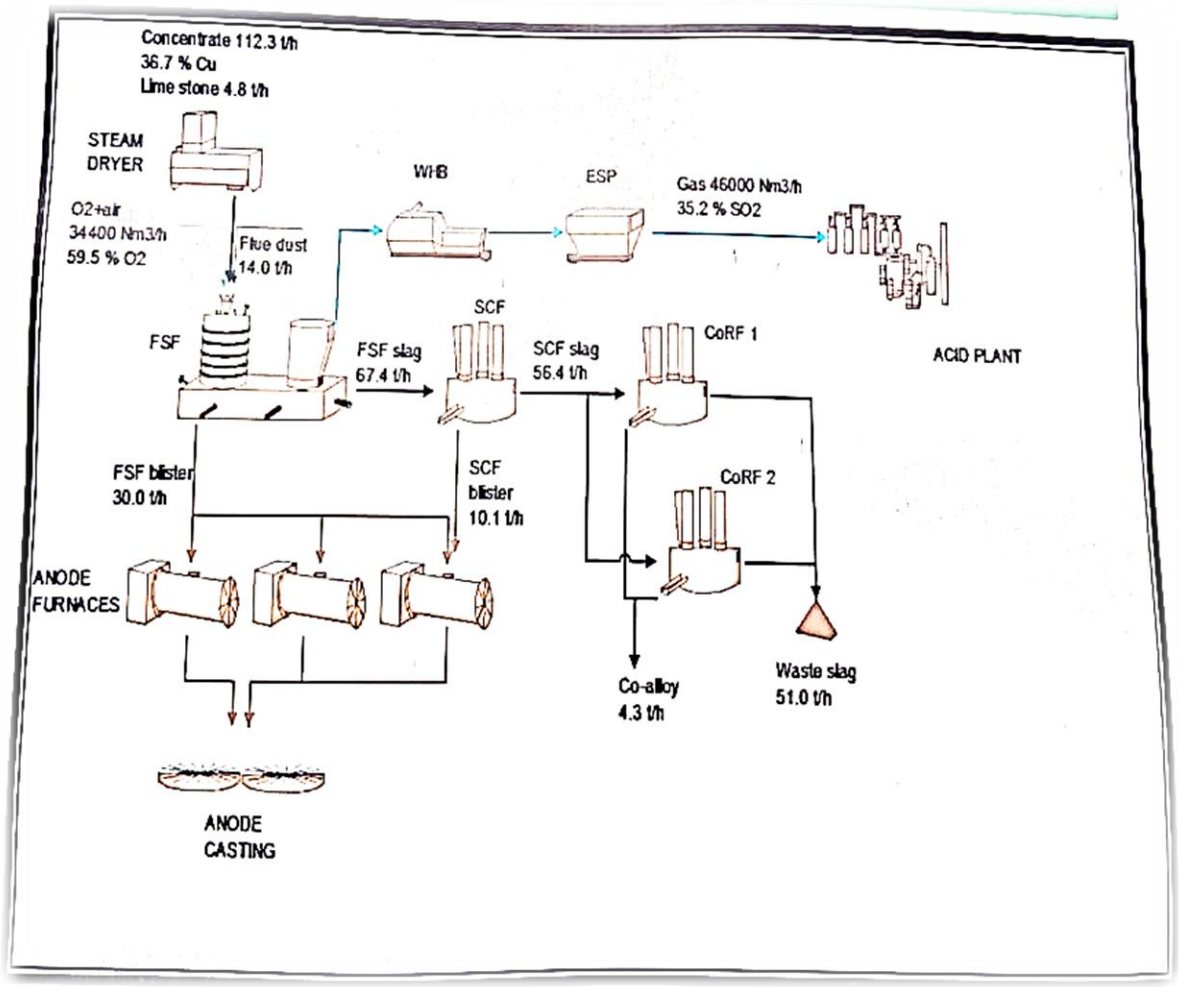

Figure 1 Nchanga Smelter Process

Overview of Power Distribution at the Smelter

The Nchanga Smelter operates on an integrated electrical distribution network supplied by the Copperbelt Energy Corporation (CEC). The primary power supply originates from the Stadium substation, where electricity is transmitted at 66 kV and stepped down to 33 kV for regional industrial distribution. From this point, power is fed along two main routes: one line supplies the Avenue substation, while another is routed directly to Substation 2, which houses the gas-insulated switchgear (GIS) that supplies the Flash Smelting Furnace (FSF), the Slag Cleaning Furnace (SCF), and the Cobalt Recovery Furnace (CoRF).

At the Avenue substation, power undergoes further distribution through four 11 kV incomers that supply Substation 1. Within Substation 1, two of the 11 kV incomers are directed to step-down transformers that reduce the voltage to 550 V at the LT section for low voltage plant loads. The remaining two 11 kV feeders form the HT section that supplies major equipment and other substations across the smelter.

From Substation 1, the 11 kV network extends to Substations 2, 3, 4, and 6, each responsible for localized distribution within their respective operational areas. At these substations, additional transformers reduce the voltage from 11 kV to 550 V for motors and auxiliary equipment, including pumps, fans, compressors, and processing plant machinery.

Substation 1/6 Operations and Maintenance Activities

Substations 1/6 supply power to a variety of motor-driven equipment essential to smelter operations. The major Equipment worked on included:

Main Air Compressor (MAC)

The Main Air Compressor (MAC) system is a 4.6 MW high-voltage motor–driven unit installed at the Acid Plant, where it performs a vital role in transporting sulfur-rich process gas through the successive stages of sulfuric acid production. Its continuous operation ensures stable gas flow necessary for oxidation, gas cooling, gas cleaning, and final conversion into sulfuric acid. As a result, the MAC is classified as a high-criticality asset within the smelter's process infrastructure.

Failure of this system would severely disrupt gas movement within the acid circuit, potentially causing the accumulation or unregulated release of sulfur-bearing gases. Such an event would have serious environmental consequences, including elevated SO_2 emissions, process upsets, and non-compliance with environmental regulatory standards. The operational reliability of the MAC therefore directly influences both process stability and environmental safety.

During the internship period, involvement with the MAC system included a range of maintenance and monitoring activities essential for sustaining performance of the 4.6 MW drive motor and associated components. Key tasks and observations included:

- Assistance in preventive maintenance on the high-voltage motor, including cleaning, terminal inspection, and tightening of power and control connections.
- Measurement of insulation resistance (IR) and continuity testing on auxiliary circuits to verify electrical integrity and detect potential degradation.

- Condition monitoring procedures, such as vibration measurements, temperature assessments, and bearing checks, to identify early indicators of mechanical or electrical faults.
- Observation of the motor starter system, including monitoring of protection relays, interlock performance, and start/stop control logic.
- Assessment of the MAC's role in process stability, particularly its influence on maintaining consistent sulfur-rich gas flow for acid production.
- Inspection of lubrication, cooling, and air-delivery subsystems, ensuring that all supporting systems remained within prescribed operational limits.

This exposure strengthened understanding of high-voltage motor reliability, predictive maintenance practices, and the broader implications of equipment performance on process efficiency and environmental protection within heavy industrial operations.

DIESEL GENERATORS

Figure 2 caterpillar 3516b

The availability of reliable auxiliary and emergency power systems is essential in any industrial environment where continuous operation supports both production efficiency and plant safety. Critical equipment such as control systems, and pollution-control units depend on uninterrupted electrical supply. Any loss of power, even for a short duration, can lead to process instability, equipment damage, or significant environmental consequences. For this reason, the smelter employs high-capacity standby generators to ensure operational continuity during grid disturbances, voltage dips, or planned electrical outages.

Valuable experience was gained through exposure to the Caterpillar 3516B IJD diesel generator sets, each rated at 2,500 kVA / 2,000 kW. These units constitute the primary backup power source for essential systems within the smelter, allowing critical loads to remain energized during any loss of supply from the main grid. Their operation supports controlled process shutdowns, protects sensitive equipment, and prevents disruptions in areas such as gas handling, furnace control, and environmental protection systems.

Work conducted on these generator units involved participation in key inspection and monitoring activities necessary for maintaining their readiness. This included routine examinations of the generator assemblies, verification of fuel, oil, and coolant levels, and assessment of battery

condition and starting reliability. Additional tasks involved monitoring temperature variations, and exhaust emissions to detect early signs of mechanical or combustion irregularities.

Further exposure was gained through involvement in generator load testing procedures, which verify performance under varying operational conditions and ensure adequate capacity to support critical loads. Observation of the synchronization panel and automatic changeover systems provided insight into how generators are integrated into the plant's electrical network, how they assume load during power interruptions, and how they return control to the grid once normal supply is restored.

Together, these experiences reinforced the essential role of standby power systems in safeguarding industrial operations, supporting equipment reliability, and ensuring environmental compliance during power disruptions.

Substation 4 Operations and Maintenance Activities

Substation 4 (SS4) supports several critical units within the smelter. The electrical systems supplied from this substation ensure the continuous operation of equipment essential for copper casting, cooling, material handling, and furnace off-gas management. Activities carried out in this section involved maintenance, monitoring, and operational inspections across multiple motor-driven systems and control panels.

Casting Wheel Motors

A major area under the responsibility of SS4 is the casting wheel section, where copper anodes are formed. Maintenance tasks included work on the motor starter panels for pumps that supply and return cooling water from the cooling towers. This cooling water is required to regulate the temperature of freshly cast anodes immediately after they exit the mold. Ensuring the functionality of these pumps is vital for maintaining controlled cooling rates, preventing thermal stress, and preserving the structural integrity of the cast anodes.

Crane

Positioned above the casting wheel is a 10-ton overhead crane used for material handling within the casting area. The crane supports lifting, positioning, and transportation of heavy components and consumables. Maintenance activities on the crane included inspections and servicing of the long-travel and cross-travel motors, thruster brakes, limit switches, and hoist motors. These tasks were essential for maintaining safe lifting operations, preventing mechanical failures, and ensuring compliance with material-handling safety standards.

off-gas Motor

Substation 4 also provides electrical supply to equipment associated with the Anode Furnace section. One critical unit in this area is the off-gas extraction motor responsible for removing sulfur-bearing gases produced during furnace operation. Maintenance tasks included inspection and testing of the off-gas motor and its control circuitry. Reliable operation of this system is necessary for controlling furnace emissions, improving workplace safety, and reducing environmental impact.

Work performed within SS4 contributed to improved understanding of motor control systems, material-handling equipment, and furnace off-gas management. The experience highlighted the importance of coordinated maintenance practices in ensuring the safety, efficiency, and reliability of equipment supporting the casting and anode-processing operations.

Incident Report: 30-Ton Crane Overload Tripping and Resulting Overheating

A critical operational incident occurred involving the 30-ton overhead crane located above the Anode Furnaces, a key material-handling unit used for charging, removing furnace components, and supporting anode-processing operations. The crane began tripping on overload shortly after startup, prompting an immediate interdisciplinary troubleshooting effort due to the potential impact on furnace operations and overall plant continuity.

Initial diagnostics focused on the electrical condition of the crane's drive motor. Winding resistance tests showed no imbalance or shorted turns, while insulation resistance measurements indicated strong and stable insulation quality. These results confirmed that the motor windings were in serviceable condition and did not contribute to the overload behavior.

A full mechanical assessment followed. The mechanical team inspected the gearbox, drive assembly, bearings, and alignment. No mechanical binding or obstruction was detected. When the motor was decoupled from the mechanical load, it operated normally without overload trips, indicating that the issue stemmed from the interaction between the motor, its drive system, and the coupled mechanical load.

Attention then shifted to the Variable Frequency Drive (VFD), which governs the crane's speed and torque. Diagnostic checks revealed abnormal output characteristics suggesting VFD malfunction. After the VFD was replaced, the crane resumed operation under load without tripping. However, a new issue emerged: the motor began to exhibit progressive overheating during operation, indicating that secondary factors such as VFD parameter mismatch, harmonic distortion, or subtle mechanical loading effects still required further investigation.

Key Learning Outcome

This incident represented a **major learning point** in understanding real-world industrial troubleshooting. It demonstrated the importance of applying a structured diagnostic approach, starting with electrical verification, followed by mechanical isolation, and ultimately drive-system evaluation. The event illustrated how faults in complex systems often extend beyond a single component and highlighted the need to consider interactions between electrical drives, mechanical loads, and control systems.

The experience provided substantial insight into fault isolation, interdisciplinary coordination, and the practical challenges of maintaining heavy industrial lifting equipment in a high-demand metallurgical environment.

Substation 2 Operations and Maintenance Activities

Electric Furnace Transformer

A key component supported by Substation 2 is the Tamini three-phase furnace transformer, which supplies the low-voltage, high-current output required for electric furnace heating. This transformer is specifically designed for metallurgical applications where controlled, high-intensity electrical energy is needed to sustain furnace temperatures, support melting operations, and maintain stable process conditions within the CoRF and other smelting units.

The unit is rated at 15 MVA, with a primary voltage of 33 kV and an open-delta secondary winding capable of delivering extremely high currents at low voltage levels (as low as 160 V depending on tap position). The transformer is equipped with an On-Load Tap Changer (OLTC) with 21 tap positions, allowing fine control of secondary voltage to match the thermal demands of furnace operation. This flexibility ensures stable furnace heating under varying process loads and contributes to the precise regulation of furnace temperature.

The transformer incorporates a D/Y-d connection scheme with an off-circuit delta/star changeover switch, enabling configuration changes as needed for specific operating modes. Cooling is achieved through an oil-cooled, water-forced cooling system, which supports the high thermal stresses typical of furnace duty. With oil and total weights of 15,000 kg and 25,000 kg respectively, the unit is engineered for heavy-duty industrial conditions.

Operational parameters indicated on the nameplate including insulation levels of LI 170 kV / AC 70 kV, temperature rise limits, and detailed current–voltage characteristics underscore the transformer's specialized role. The ability to deliver high secondary currents (up to several tens of kilo-amperes) is essential for effective furnace heating, slag superheating, and process stability.

The presence of this transformer is therefore fundamental to furnace performance. It provides:

- Reliable delivery of high-current furnace heating power
- Voltage adjustability via OLTC to match metallurgical requirements
- Electrical isolation and protection between the high-voltage network and furnace circuits
- Thermal robustness suitable for continuous heavy-load operation

Understanding this transformer and its operating characteristics contributed to deeper insight into furnace power systems, safety considerations, and the critical importance of transformer health in sustaining uninterrupted smelting operations.

Maintenance activities on this apparatus focused on ensuring electrical integrity, thermal stability, and reliable operation under the high-stress conditions typical of electric furnace systems. Routine tasks included insulation resistance testing, winding resistance measurements, and transformer ratio checks to verify the health of the windings and tap changer circuitry. Oil quality was monitored through dissolved gas analysis and periodic filtration to maintain dielectric strength. The on-load tap changer (OLTC) received regular inspection and cleaning to prevent contact wear, overheating, or switching failure. Cooling system components particularly the oil-to-water heat exchangers, pumps, and sensors were inspected to confirm proper circulation and effective heat dissipation. Structural checks on bushings, terminals, and gasketed joints were carried out to identify leaks or mechanical deterioration. These mandatory maintenance activities were essential in sustaining stable furnace operation and preventing costly unplanned outages.

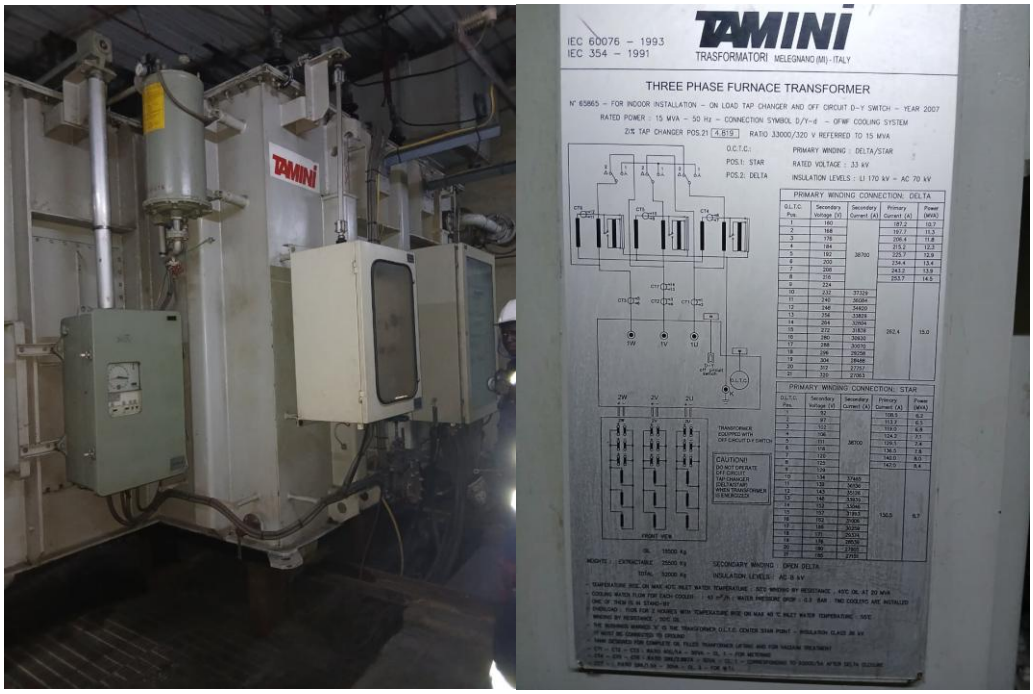

Figure 3 Three phase Furnace transformer

Slurry Pump Motor

Another critical item of equipment associated with Substation 2 is the slurry pump motor, which is responsible for transporting cobalt-rich alloys mixed with water to the screening system. This screening unit comprising a screw conveyor and vibro motors, separates and conditions the material for subsequent processing. The slurry pump forms the first link in this chain, and its failure immediately halts the movement of Co-alloys, effectively forcing the entire plant to cease operation. Owing to this high operational significance, strict preventive maintenance practices were implemented to ensure high reliability and continuous availability.

Preventive maintenance activities for the slurry pump motor included routine cleaning to remove accumulated slurry residues that could hinder cooling or affect mechanical components. Electrical inspections were performed to assess insulation resistance, verify continuity, and check terminal tightness, ensuring stable power delivery and reducing the risk of electrical faults. Motor alignment and coupling integrity were evaluated regularly to prevent

undue stress on shafts and bearings. Bearing lubrication was monitored and replenished as required to reduce friction and prevent overheating. Vibration measurements and temperature monitoring were conducted to detect early signs of imbalance, misalignment, or mechanical wear. The motor starter panel, overload relays, and protection settings were reviewed periodically to confirm proper functioning during startup and fault conditions. These preventive maintenance tasks were essential in sustaining the reliability of the slurry pumping system, thereby safeguarding continuous cobalt recovery operations.

Conclusion

The industrial attachment provided extensive exposure to the electrical systems that support critical metallurgical processes within the smelter. Although this report highlights only selected major pieces of equipment, the scope of work undertaken during the attachment was considerably broader. A wide range of tasks involving power distribution systems, furnace auxiliaries, cranes, pumps, cooling systems, and material-handling equipment were performed throughout the different substations. Despite the diversity of plant operations, the central theme across all maintenance activities was motor control and motor reliability. Nearly every essential process from air supply, slag handling, cooling, furnace operation, screening, cobalt recovery, and casting ultimately depended on electrically driven motors.

As a result, the attachment offered significant learning opportunities in motor diagnostics, protection systems, preventive maintenance, and operational troubleshooting. The experience strengthened understanding of electrical system reliability, industrial safety, process interdependencies, and the importance of well-structured maintenance practices in ensuring uninterrupted plant performance. In summary, the attachment successfully bridged theoretical knowledge with practical industrial application, providing a strong foundation for future professional development within the field of electrical engineering.